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Ion-Exchange Studies for Removal of Uranium and Selenium

in

Rocky Flats Groundwater

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ION-EXCHANGE STUDIES FOR REMOVAL OF URANIUM AND SELENIUM IN ROCKY FLATS GROUNDWATER

U.S. DEPARTMENT OF ENERGY
The Rocky Flats Environmental Technology Site
Golden, Colorado

ENVIRONMENTAL RESTORATION PROGRAM DIVISION

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TABLE OF CONTENTS

Section **Page**

Figure

Table

Appendices

5

1.0 INTRODUCTION

The Ion-Exchange Treatability Study was performed under the Sitewide Treatability Studies Program (STSP) to evaluate the effectiveness of nine ion-exchange resins in removing uranium (U) and selenium (Se) from groundwater wells GW3086 and B206789 at Rocky Flats Environmental Technology Site (RFETS). The ion-exchange resins used in this study are shown in Table 1.0-1.

Table 1.0-1 Ion-Exchange and Resin Type

Ion Exchange Resin	Manufacturer	Resin Type
Amberlite 200C	Rohm and Haas Co.	Strong Acid Cation
Amberlite DP-1	Rohm and Haas Co.	Weak Acid Cation
Amberlite IRC-718	Rohm and Haas Co.	Metals Chelating
Amberlite IRA-938	Rohm and Haas Co.	Strong Base Anion
Purolite A-400	Purolite Company	Strong Base Anion
Ionac A-642	Sybron Chemical Co.	Strong Base Anion
Dowex 21K	Dow Chemical Company	Strong Base Anion
Diaion PA-308	Mitsubishi Kasei Corp.	Strong Base Anion
Diaion CR-11	Mitsubishi Kasei Corp.	Metals Chelating

The work was performed by Environmental Engineering Technology and Environmental Technologies in accordance with the general guidelines of the Treatability Study Work Plan (TSWP) for Ion-Exchange Processes and Adsorption Processes (June 1993).

Previous work (Roushey, October 1993; Laul and Muller, October 1994) has shown that plutonium (Pu) and americium (Am) in groundwater (i.e., Wells GW09091 and GW06991) can be removed by filtration through a 0.45 micron (μm) filter, to levels below the potential Applicable or Relevant and Appropriate Requirements (ARAR) value of 0.05 picocuries per liter (pCi/L). The plutonium and americium in RFETS groundwater appear to have been associated with the total suspended solids (TSSs) and/or in colloidal form. Their removal was verified by comparing the filtered and unfiltered groundwater results of Well GW09091, which contained high concentrations of plutonium (10 to 350 pCi/L) and americium (10 to 40 pCi/L).

It was noted that metals such as aluminum (Al), arsenic (As), copper (Cu), chromium (Cr), iron (Fe), lead(Pb), manganese (Mn), vanadium (V), and zinc (Zn) in groundwater were also associated with the TSS and/or colloids. Similarly, their removal below the respective ARAR values was achieved by filtration through a 0.45 μm filter. The successful removal of these metals of concern was verified by comparing the filtered and unfiltered results of 13 groundwater wells (i.e., 0386, 03691, 01491, 05691, 1786, 2286, 3886, 4086, 7287, 12491, 13491, B206789, and B400389).

However, uranium and selenium concentrations in the filtered and unfiltered groundwater remained the same. Uranium in GW3086 was present at 66.7 pCi/L (200 micrograms per liter (μg/L)), while the ARAR value is 5 pCi/L. Selenium was present at about 600 μg/L level in Well B206789, while the ARAR value is 10 μg/L.

Thus, this report focuses on the removal of uranium and selenium from RFETS groundwater, although pertinent metal and anion data are discussed for wells GW3086 and B206789. The groundwater samples from the two wells were combined in a 1:1 ratio to perform bench scale column and batch experiments. Column experiments showed that uranium was effectively removed (>99.9 percent) by eight ion-exchange resins (except Amberlite 200C, strong acid cation). Selenium was less effectively removed by four ion-exchange resins (i.e., Purolite A-400, Ionac A-642, Diaion PA-308, and Dowex 21K, all strong base anion types). Uranium and selenium were effectively retained by strong base anion resin, suggesting that uranium and selenium were present in an anionic form in the groundwater.

The batch experiments with resin weight to solution volume ratios of 1:50, 1:100, 1:200, and 1:400 were conducted to evaluate the relative loading capacity and adsorption isotherms of the favorable resins. The mean batch Kd (partition coefficient) values for uranium using Amberlite IRA-938, Purolite A-400, Ionac A-642, and Diaion PA-308 are 4.8 x 10^3 ml/g, while that for Dowex is 21K is 8.1 x 10^3 ml/g. Likewise, the mean batch Kd values for selenium using Purolite

A-400, Ionac A-642, and Diaion PA-308 are about 170 ml/g, while that for Dowex 21K is 220 ml/g.

Uranium was more effectively removed than selenium. Dowex 21K appeared to be the best ion-exchange resin for uranium and selenium removal. These ion-exchange resins can be regenerated and reused, which can reduce cost and minimize generation of secondary wastes.

1.1 SITE DESCRIPTION

1.1.1 Site Name and Description

RFETS, a 6,550 acre industrial reservation, is located in northern Jefferson County, Colorado. RFETS lies on Alluvium and Arapahoe bedrocks, two major geological geostrata units. The Alluvium consists of weathered claystone (Kacl) and the underlying Arapahoe bedrock consists of weathered and unweathered sandstone (Kass). Based on the geology and stratigraphy, the Alluvium units are more permeable to groundwater than the Arapahoe bedrock units (U.S DOE 1991, 1992).

Groundwater sampling was conducted from March to June of 1994. Monitoring Well GW3086 is in the vicinity of the Solar Evaporation Ponds (SEPs) and is located in Operable Unit (OU) 8. It penetrated 14.9 ft to the Araphoe formation and had a slow rate of recharge. The pH of Well GW3086 was 7.6, which indicated a predominance of a bicarbonate medium. Its TDS was 3800 milligrams per liter (mg/L). Well GW3086 had a uranium concentration of 200 μg/L (66.7 pCi/L) which has been the greatest among all wells sampled to date. Pu-239 and Am-241 concentrations in the filtered and unfiltered samples from GW3086 were below the ARAR value of 0.05 pCi/L. All the other Contaminants of Concern (COC) (i.e., Be, Cr, Fe, Pb, Mn, Hg, and Se) were also below their ARARs except for iron, which was high at 1600 μg/L. The iron concentration was reduced to <10 μg/L by filtering, which successfully met its ARAR of 300 μg/L.

B206789 is a monitoring well in the vicinity of Landfill Pond in OU7. The well penetrated 20 ft to the Arapahoe formation and had a slow rate of recharge. The U-238 level was (5.0 μg/L) 1.7 pCi/L, and the Pu-239 and Am-241 concentrations were below 0.05 pCi/L in the filtered and unfiltered samples. The other COC, except selenium, were also below their potential ARARs. The selenium concentration was approximately 600 µg/L in the filtered and unfiltered waters. The pH of the groundwater from Well B206789 was 7.8, indicating a predominance of a bicarbonate medium. The total dissolved solids (TDS) was 1200 mg/L.

1.1.2 History of Operations

From the mid-1950s to the present, RFETS has been a government-owned (i.e., Department of Energy (DOE)), contractor-operated facility which manufactured weapon components primarily from plutonium, uranium, beryllium, and stainless steels. RFETS had also reprocessed certain plutonium residues for the recovery of weapons grade plutonium. This process included a variety of chemicals, solvents, and their by-products, which resulted in waste streams and discharges.

From the 1960s to the 1970s, five SEP (i.e., 207A, 207B North, 207 Center, 207 South, and 207C) were constructed. These ponds received and stored liquid wastes and discharges from various buildings at RFETS. The liquid waste streams contained radionuclides including U-234, U-235, U-238, Pu-239+240, and Am-241 and metals including aluminum, lithium (Li), manganese, potassium (K), strontium (Sr), selenium, zinc, and anions such as bicarbonate, chloride, nitrate/nitrite, and sulfate. The concentrations of these radionuclides, metals, anions, and TDSs varied widely over two orders of magnitude. Over time, contaminants migrated into the subunits of the Alluvium and Arapahoe bedrock formations.

1.2 WASTE STREAM DESCRIPTION

1.2.1 Waste Matrices

Groundwater from Well GW3086 contained uranium at approximately 200 µg/L and selenium at <1 µg/L. Well B206789 contained uranium at 5 µg/L and selenium at approximately 600 µg/L. The concentrations of uranium and selenium were the same in the filtered and unfiltered samples, which indicated that they were present in dissolved (i.e., soluble) form. These filtered groundwater samples (i.e., 5 galions each) were combined in a 1:1 ratio and then used as the feed solution for the column and batch tests. The concentrations of uranium, selenium, major cationic, and anionic compositions of the individual groundwater samples and feed solution are shown in Table 1.2.1-1

Table 1.2.1-1 Composition of Wells GW3086 and B206789 and Feed Solution

Analyte	Well GW3086	Well B206789	Feed Solution
Uranium (µg/L)	200	5.0	105
Selenium (µg/L)	<1	600	300
Calcium (mg/L)	290	160	150
Potassium (mg/L)	31	3.6	13
Magnesium (mg/L)	83	44	61
Sodium (mg/L)	650	140	410
Bicarbonate (mg/L)	390	180	140
Nitrate (mg/L)	560	6.7	280
Chloride (mg/L)	110	72	97
Sulfate (mg/L)	220	590	400
Total Dissolved Solid (mg/L)	3800	1200	2400
pH	7.6	7.8	7.7

The uranium and selenium and major cationic and anionic compositions of the feed solution matched the individual components, except for calcium and bicarbonate, which may be due to the precipitation of calcium bicarbonate. However, no precipitation was observed in the feed solution during the weeks the experiments were conducted.

1.2.2 Pollutants/Chemicals

The TSWP listed the metals and radionuclides of concern and the potential ARARs are shown in Table 1.2.2-1.

Table 1.2.2-1 Potential ARARs for COCs

Element	Potential ARAR
Beryllium	4 µg/L
Chromium	50 µg/L
Iron	300 µg/L
Lead	15 µg/L
Manganese	50 µg/L
Mercury	2 µg/L
Selenium	10 µg/L
Uranium (Total)	5 pCi/L
Plutonium	0.05 pCi/L
Americium	0.05 pCi/L

Plutonium, americium, and most other metals of concern can be removed below their potential ARARs by filtration through a 0.45 µm filter (Roushey, October 1993; Laul and Muller, October 1994). Only uranium, from Well GW3086, and selenium, from Well B206789, had concentrations in the filtered and unfiltered waters that remained the same and above the ARARs. Nine ion-exchange resins were tested for their effectiveness in the removal of uranium and selenium (See Table 1.0-1).

1.3 TREATMENT TECHNOLOGY DESCRIPTION

1.3.1 Treatment Process and Description

Bench scale studies involved column experiments with a continuous rate of flow and batch experiments with varying resin weight to solution volume ratios. Figure 1.3.1-1 shows a schematic of a column experiment. The cylindrical column had a 2.5 centimeter (cm) diameter and was filled with a 15 cm height of adsorbent. A peristaltic pump, with a constant flow of 1.5 to 2.0 milliliters per minute (ml/min), moved the feed solution through the column. The bed volume ranged from 50 to 60 cubic centimeters (cc), which gave a column residence time of 20 to 30 minutes. The treated effluent was collected in a one gallon plastic container for subsequent analysis.

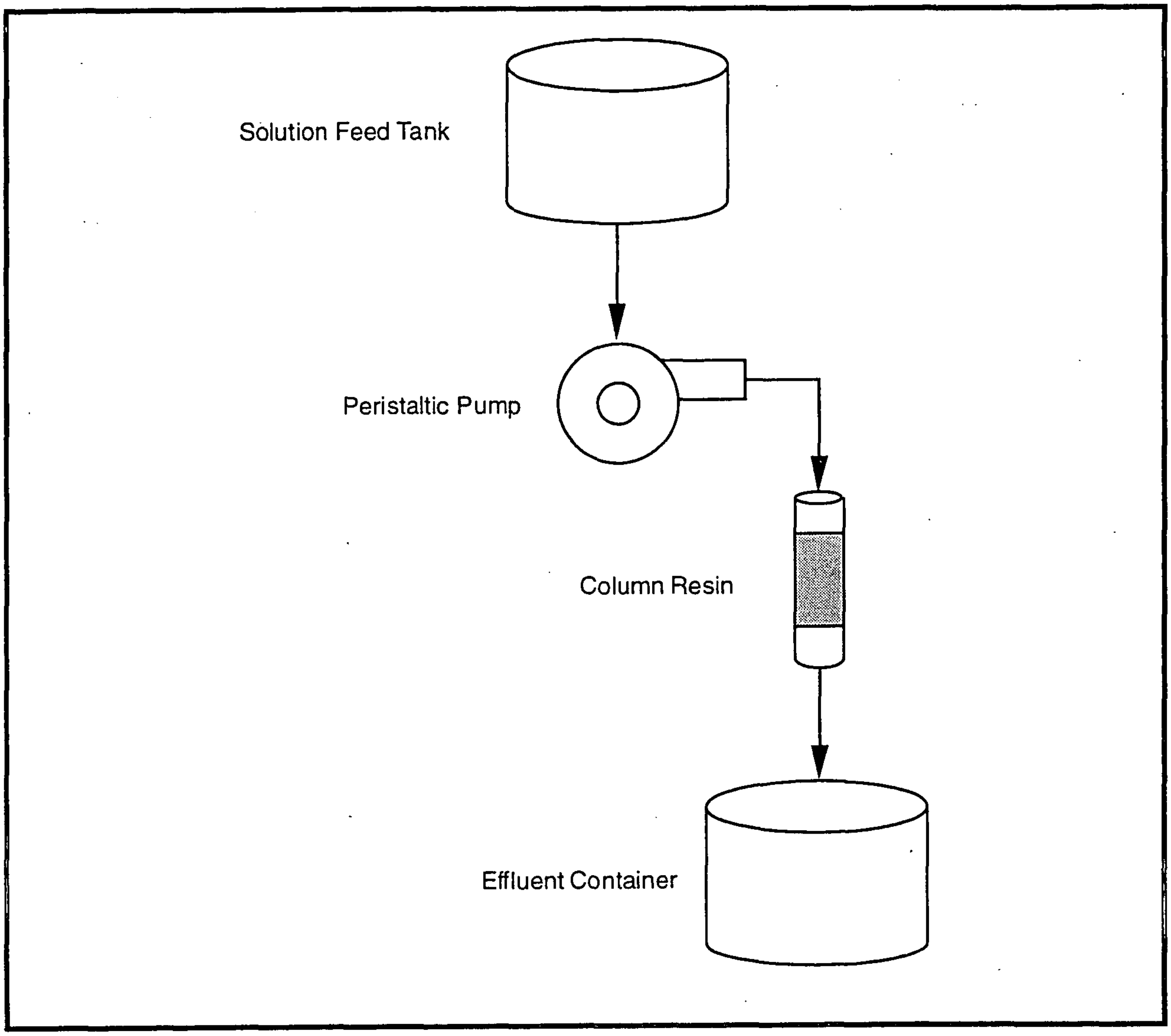

Figure 1.3.1-1 Schematic of Ion-Exchange Treatability Tests

The batch experiments consisted of resin weight to solution volume ratios of 1:50, 1:100, 1:200, and 1:400 using 50 ml feed solution in a plastic bottle for each test. The bottles were tumbled at thirty revolutions per minute for approximately 24 hours. The solutions were then filtered using a 0.45 μm filtration apparatus. Different aliquots were taken to determine the pH and uranium and selenium concentrations using RFETS analytical facilities. Also, one experiment for the four favorable resins (strong base anion) was conducted using a large volume of feed solution (1 to 2 liters) and a resin weight to solution volume ratio of 1:400. These analysis was performed by Accu-Labs Research, Inc., in Golden, Colorado, for various analytes – metals, radionuclides, anions, TDS, and pH (See Section 3.4.2).

1.3.2 Operating Features

Due to a slow recharge rate, groundwater samples from Wells GW3086 and B206789 were collected over a four to five day period in 10, one-gallon plastic containers. The waters were filtered through a 0.45 µm filter and combined in a 1:1 ratio to form a single uniform sample. This feed solution (10 gallons) was used for the column and batch experiments with the nine ion-exchange resins whose properties (i.e., type, manufacturer, mesh size, and the quantity used for the column experiments) are shown in Table 1.3.2-1.

Table 1.3.2-1 Ion-Exchange Experiments

Ion Exchange Resin*	Resin Type	Manufacturer	Size-Mesh	Quantity (g)**
Amberlite 200C	Strong Acid Cation	Rohm and Haas Co.	-16 to +30	55
Amberlite DP-1	Weak Acid Cation	Rohm and Haas Co.	16 to 50	54
Amberlite IRC-718	Metals Chelating	Rohm and Haas Co.	16 to 50	53
Amberlite IRA-938	Strong Base Anion	Rohm and Haas Co.	20 to 50	42
Purolite A-400	Strong Base Anion	Purolite Company	16 to 50	60
Ionac A-642	Strong Base Anion	Sybron Chemical Co.	16 to 50	51
Dowex 21K	Strong Base Anion	Dow Chemical Company	16 to 50	56
Diaion PA-308	Strong Base Anion	Mitsubishi Kasei Corp.	16 to 50	51
Diaion CR-11	Metals Chelating	Mitsubishi Kasei Corp.	16 to 50	53

* These resins can be regenerated.
** Quantity used in 2.5 cm x 15 cm column.

The operating parameters for the column experiments are shown in Table 1.3.2-2. The batch Kd experiments were performed with resin weight to solution volume ratios of 1:50, 1:100, 1:200, and 1:400 using 50 ml of feed solution. The mixtures, in plastic bottles, were tumbled for approximately 24 hours with a constant speed of thirty revolutions per minute. The solutions were then filtered through a 0.45 µm medium. Different aliquots were taken for the analysis of pH, uranium, and selenium.

Table 1.3.2-2 Operating Features of Column Experiments

Column Dimension	2.5 cm ID x 30 cm Height
Resin Height	15 cm
Bed Volume	50 – 60 cc
Feed Solution pH	7.7: GW3086 (50%) and B206789 (50%)
Solution Feed Rate	1.5 – 2.0 ml/Min
Column Residence Time	20 – 30 Minutes
Effluent Collected	3.0 Liters (60 Column Volumes)
Effluent pH	7.6 – 7.9 for Strong Base Anion 8.3 – 9.7 for Strong/Weak Acid Cation 10.3 – 10.7 for Metal Chelating

1.4 PREVIOUS TREATABILITY STUDIES AT THE SITE

The ion-exchange study was one of the five groundwater treatment technologies identified in the Final Treatability Studies Plan (FTSP) (August 1991). The TSWP for ion-exchange processes (June 1993) identified six resins (See Table 1.4-1) for evaluation to effectively remove metals and radionuclides of concern (i.e., Be, Cr, Fe, Pb, Mn, Hg, Se, Am, Pu, and U). For the majority of ion-exchange resins, minimal information existed regarding the removal of radionuclides (i.e., Pu, Am, and U) and some metals (i.e., Be, Cr, and Se) from the RFETS groundwater (See Table 1.4-1).

TSWP (June, 1993) identified the feed solution as a mixture of groundwater from Wells GW09091 (40 percent) and B206789 (30 percent) and surface water GS10 (30 percent). However, the previous adsorption study (Roushey, October 1993) showed that the levels of COC in the filtered water were extremely low. A re-evaluation of the existing groundwater data, from 1990 to present, stored in the Rocky Flats Environmental Data Base (RFEDS) was performed to identify wells and the levels of contaminants that would be suitable for treatability studies (Laul and

Muller, October 1994). Groundwater from Well GW3086, containing uranium, and Well B206789, containing selenium, were selected for the ion-exchange study.

Table 1.4-1 Constituent Removal Effectiveness for the Resins To Be Tested

		Heavy Metals							Radionuclides		
Ion Exchange Resin	Resin Type	Be	Cr	Fe	Pb	Mn	Hg	Se	Am	Pu	U
Amberlite 200C	Strong Acid Cation	●	O[1]	●	●	x	●	O	*	*	O
Amberlite DP-1	Weak Acid Cation	●	O	●	●	●	●	O	NI	NI	O
Amberlite IRC-718	Metals Chelating	NI	O	O[2]	●	O	●	O	NI	NI	O
Amberlite IRA-938	Strong Base Anion	O	●	O	O	O	O	●	O	O	●
Dianex TS-200	Hg-Selective Chelating	NI	O	*	●	*	●	O	NI	NI	O
HiPAC PEI	Metals Chelating	NI	O	O	O	O	●	O	NI	NI	O

Legend:

- ● Target Constituent
- * Potentially Effective
- O Not Effective
- x Mn is Not Effectively Removed by Amberlite 200C
- NI No Information Available To Evaluate Effectiveness

The anticipated removal effectiveness of these resins are based on the assumed ionic species shown in Table 6-2 of TSWP, June 1993.

1 It is assumed that the Cr will be present in the hexavalent state.

2 It is assumed that Fe II will be present in dissolved form, while Fe III will be present in particulate form and, therefore, will settle out of the water before testing. This resin is not effective at removing Fe II, but is effective at removing Fe III.

2.0 CONCLUSIONS AND RECOMMENDATIONS

2.1 CONCLUSIONS

Plutonium and americium radionuclides and metals including aluminum, arsenic, copper, iron, chromium, lead, manganese, vanadium, and zinc appear to be associated with TSS and/or in colloidal form. They can be removed below their potential ARARs by filtration through a 0.45 µm medium. Among the 10 COC (i.e., Be, Cr, Fe, Pb, Mn, Hg, Se, Pu, Am, and U), only uranium, in Well GW3086 (U 200 µg/L or 66.7 pCi/L), and selenium, in Well B206789 (Se 600 µg/L), had concentrations greater than the potential ARAR (5 pCi/L for U and 10 µg/L for Se) in the filtered and unfiltered groundwater samples.

In the ion-exchange column experiments, uranium was effectively removed (>99.9 percent) by eight ion-exchange resins (except Amberlite 200C), and the effluent concentrations were well below the potential ARAR. Selenium was also removed by four strong base anion type resins: (1) Purolite A-400, (2) Ionac A-642, (3) Diaion PA-308, and (4) Dowex 21K. These effluent concentrations were below the potential ARAR.

The retention factor (RF) is defined as the ratio of solute concentration in the influent to solute concentration in the effluent, and is used as a measure of removal effectiveness. The RFs for uranium removal ranged from 2100 to 5250 for the eight favorable resins, while the RFs for selenium are >60 for the four favorable strong base anion resins. In all cases, the effluent concentrations were below the potential ARARs. Results from the strong base anion resins suggested that uranium and selenium appear to be present largely in an anionic form in groundwater.

The batch Kd experiments with resin weight to solution volume ratios of 1:50, 1:100, 1:200, and 1:400 were conducted to evaluate the relative loading capacity and adsorption isotherms of the favorable resins. The mean batch Kd values for uranium removal using Amberlite IRA-938, Purolite A-400, Ionac A-642, and Diaion PA-308 were 4.8×10^3 ml/g, while that for Dowex 21K was 8.1×10^3 ml/g.

The mean batch Kd values for selenium removal using Purolite A-400, Ionac A-642, and Diaion PA-308 were 1.7 x 10^2 ml/g, while that for Dowex 21K was 2.2 x 10^2 ml/g. Overall, uranium removal was more effectively accomplished than selenium removal, and Dowex 21K appeared to be the most effective resin for this application. All of the favorable resins can be regenerated, thus maximizing their use, and thereby, minimizing cost and generation of secondary wastes.

2.2 RECOMMENDATIONS

This study identified eight ion-exchange resins for uranium removal and four ion-exchange resins for selenium removal from RFETS groundwater. Among them, Dowex 21K was the best performer. Before being used on a pilot scale, break-through curves should be established to validate the batch Kd values for the selected resins. In addition, periodic analyses of the effluents should be performed to ensure that the uranium and selenium concentrations did not exceed the potential ARAR values.

The batch Kd values for uranium and selenium were established by combining the two groundwater from Wells GW3086 and B206789. It is uncertain whether the batch Kd values for uranium and selenium would remain the same or if the values would change when individual well waters were used. A separate experiment should be conducted to verify the column retention factors and batch Kds for uranium and selenium using individual well waters.

Per the manufacturers, these ion-exchange resins can be regenerated and reused which could reduce overall cost and also minimize the generation of secondary wastes. However, a regenerated resin needs to be tested for its performance effectiveness to determine the number of times it can be regenerated before it is replaced with a new resin.

3.0 TREATABILITY STUDY APPROACH

3.1 TEST OBJECTIVES AND RATIONALE

The main objective of this study was to evaluate the effectiveness of nine ion-exchange resins as a remedial technology for removing radionuclides and metals of concern from the groundwater at RFETS. These results could be integrated into the Feasibility Study (FS) process for potential application to one or more OUs.

Since previous work (Roushey, October 1993; Laul and Muller, October 1994) has shown that plutonium, americium, and most other metals of concern can be removed below the potential ARARs by filtration through 0.45 μm membrane, the focus was on uranium and selenium removal from Wells GW3086 and B206789, respectively. The uranium concentration was 200 μg/L or 66.7 pCi/L, and its ARAR is 5 pCi/L. The selenium concentration was approximately 600 μg/L, and its ARAR is 10 μg/L. The purpose of this study was to find effective resins. Within that context, the rationale was to determine retention factors and batch Kd values for the loading capacities and adsorption isotherms of the favorable ion-exchange resins.

3.2 EXPERIMENTAL DESIGN AND PROCEDURES

The study was conducted in three phases: (1) Phase 1 involved column experiments with a continuous downward flow; (2) Phase 2 involved batch experiments with resin weight to solution volume ratios of 1:50, 1:100, 1:200, and 1:400 with a small volume of feed solution (50 ml); and (3) Phase 3 involved repeat of batch experiment at 1:400 ratio with a large feed solution volume (1.0 liter).

The Phase 1 column tests simulated the performance characteristics of each resin similar to its application as a remediation technology in the field. Figure 1.3.1-1 shows a schematic of the column experiment. The column description and operating parameters are outlined in Section 1.3. Using EG&G analytical facilities, the effluents from each column were frequently analyzed to determine which resins were retaining uranium and/or selenium. Eight resins proved effective for uranium removal and four resins for selenium removal.

Phase 2 batch experiments were performed on the favorable resins with varying resin weight to solution volume ratios to evaluate the relative loading capacities and the nature of the adsorption isotherms (i.e., linear or non-linear). Batch Kd values also lend information on the equilibrium states of uranium and selenium. Based on the comparison of influent/effluent ratios between the batch Kd values (1:50) and the column tests, an equilibration seemed to be reached in 20 to 30 minutes residence time in the column experiments.

Phase 3 involved a repeat of the batch experiment at a 1:400 ratio with a large volume of feed solution (1.0 liter). The solution was analyzed for various analytes such as pH, TDS, metals, anions, total uranium, U-234, and U-238 by Accu-Labs Research, Inc. This allowed a comparison to be made with the pH, uranium, and selenium results obtained by EG&G facilities.

3.3 EQUIPMENT AND MATERIALS

Materials used included common laboratory glassware, plastic bottles, beakers (i.e., glass and plastic), columns and peristaltic pump (from BIO-Rad), and tubing. The nine ion-exchange resins that were examined are shown in Table 1.3.2-1. The EG&G analytical equipment used included a pH meter (Orion 230A); Kinetic Phosphorescence Analyzer (Chem Check KPA-11) for uranium analysis; and graphite furnace atomic absorption (GFAA) (Perkin Elmer model 5100Z) for selenium analysis.

3.4 SAMPLING AND ANALYSIS

The sampling of groundwater at Wells GW3086 and B206789 was conducted according to proper protocol by a subcontractor to the Environmental Restoration Program Division (ERPD) of EG&G, using operating procedure for groundwater sampling (OPS-GW-06, March 1992). The water samples were brought to Treatability Study Laboratory 264 in Building 881 in accordance with Procedure OPS-4-11000-ER-OPS-F0.13 (Rev.2, May 1992). The samples were then filtered through a 0.45 μm filter and combined into a single container for subsequent column and batch experiments.

The pH values were measured using a Orion pH meter that was calibrated with standard buffer solutions with pH values of 7 and 10. The KPA-11 was calibrated with uranium standards in the part per billion (ppb) range (33.3, 16.7, 8.33, and 3.33 nanograms per milliliter (ng/ml)) to ensure consistency in the analytical procedure. A uranium standard of 16.7 ng/ml was prepared and run as an internal standard for each batch of samples. The KPA-11 is selective, rapid, and sensitive for uranium at or below the ppb level (0.1 pCi). The errors associated with the results are approximately 10 percent.

For selenium, five standards ranging from 25 to 200 µg/L were used for calibration (i.e., non-linear) in each batch of samples. The GFAA is also selective (i.e., using selenium lamp), rapid, and sensitive down to 1 µg/L or 1 ppb. The sample injection required only 0.020 ml, and some samples were analyzed in duplicate. Due to the low volume injections, the errors ranged from 10 to 20 percent.

Samples were also analyzed by Accu-Labs Research, Inc., in Golden, Colorado, for complete characterization of analytes such as pH, TSS, TDS, metals, anions, and radionuclides. The analytes, their mode of measurement, equipment used, and the Environmental Protection Agency (EPA) approved reference method are shown in Table 3.4-1.

3.4.1 Waste Stream

The only potential waste stream generated from this process would be spent ion-exchange resins and any metals and radionuclides stripped from recycled resins. For a large scale treatment system, disposal of spent ion-exchange resins could be a significant issue.

3.4.2 Treatment Process

The treatment process is outlined in Section 1.3.1. Bench scale column tests simulated actual field demonstration, while batch tests yielded information on the loading capacities, break-through, and the nature of the adsorption isotherms.

Table 3.4-1 Method of Analysis by Accu-Labs Research, Inc.

Analyte and Mode	Euipment Used	EPA Ref Method
pH	pH Meter (Orion 720)	310.1
TDS by Gravimetric	Mettler AE200 Balance	160.1
TSS by Gravimetric	Mettler AE200 Balance	160.2
Metals by ICP		
Ag, Al, Ba, Be, Ca, Cd Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, Sb, Tl, V, and Zn	Perkin Elmer 2000 Thermal Jarrell-Ash 61	200.7
Metals by GFAA		
As	Perkin Elmer 5000, 5000Z or 4100ZL	206.2
Se	Perkin Elmer 5000, 5000Z or 4100ZL	270.2
Pb	Perkin Elmer 5000, 5000Z or 4100ZL	239.2
Hg by Cold Vapor	Leeman PS200	245.1
Anions		
Alkalinity, CO_3, HCO_3 by Titration	Pipett, Burrette	310.1
Cl by Calorimetric	Technicon ASII Autoanalyzer	325.2
NO_3 by Calorimetric	Technicon ASII Autoanalyzer	353.2
SO_4 by Turbidimetric	Milton Roy Spec 301	375.4
Radionuclides		
Total Uranium by KPA	KPA-11, Chem Check	ASTM-D5174-91
U-238, U-234 by Radiochemistry	Alpha Spectrometry Nuclear Data and Canberra	Procedure*
Pu-239+240 and Am-241 by Radiochemistry	Alpha Spectrometry Nuclear Data and Canberra	Procedure*

*Procedures used for the analysis of radionuclides U-234, U-238, Pu-239+240, and Am-241 are standard radiochemical separations coupled with alpha spectrometry. The results reported by Accu-Lab Research, Inc. are shown in Appendix A.

3.5 DATA MANAGEMENT

All the information pertinent to column and bench tests were recorded in a bound notebook devoted to treatability studies. The results from the uranium analyzer (KPA-11) and the selenium analysis GFAA were processed internally. The computers printed detailed information which was also saved as a hard copy. This data was also saved as a backup on the hard disk of the computer. A separate notebook was assigned for uranium.

Accu-Labs Research, Inc. followed EPA's approved procedures and protocols for the analysis of various analytes listed in Table 3.4-1. All the raw data was archived by Accu-Labs Research, Inc. EG&G received the final data in report form (See Appendix A).

3.6 DEVIATION FROM THE WORK PLAN

There were some deviations from the Work Plan which were discussed and approved by DOE, the Rocky Flats Field Office (RFFO), the Colorado Department of Public Health and Environment (CDPHE), and EPA during the study. The Work Plan identified three wells (i.e., GW09091, B206789, and GS10) in the respective proportion of 40 percent, 30 percent, and 30 percent as a feed solution to test six ion-exchange resins for the removal of 10 COC (i.e., Be, Cr, Fe, Pb, Mn, Hg, Se, U, Pu, and Am). As discussed in Section 1.4, the COC concentration levels in that feed were considerably lower than were indicated in the Work Plan (Roushey, October 1993). A re-evaluation of the RFEDS data was performed to identify wells and the concentrations of COC (Laul and Muller, October 1994). It was noted that Pu and Am radionuclides in Well GW09091 and COC such as Cr, Fe, Pb, and Mn in groundwater can be removed (below their ARARs) by filtration through a 0.45 μm medium. The Be and Hg were already below their ARARs. Therefore, the focus was on uranium and selenium. Groundwater from Well 3086 (uranium) and Well B206789 (selenium) was selected for analysis for this treatability study.

The resin Dianex TS-200 is a Hg-selective chelating type (See Table 1.4-1). No groundwater at RFETS contains Hg above its ARAR, so this resin was replaced with two other resins to test for uranium and selenium removal: (1) Diaion PA-308 (strong base anion) and (2) Diaion CR-11 (metals chelating). The resin HiPAC PEI (metals chelating resin) is a proprietary material, but it was not tested. A metal chelating resin, such as HiPAC PEI, appeared effective only for uranium and not for selenium. The effluent pH was also high, which made it less attractive. Instead, three other strong base anion resins were selected: (1) Purolite A-400, (2) Ionac A-642, and (3) Dowex 21K. Thus, a total of nine ion-exchange resins, instead of the six identified in the Work Plan, were studied.

The Work Plan specified that capability and capacity (breakthrough) tests be performed by passing large volumes of feed solution at different flow rates through the columns. Because groundwater samples were limited (i.e., slow rate of recharge), the same objectives were accomplished by batch experiments with varying resin weight to solution volume ratios of 1:50, 1:100, 1:200, and 1:400 using a small volume (50 ml) of feed solution. Normally one resin weight to solution ratio (test/experiment) is performed. Four resins weight to solution volume ratios were used to define the isotherm. The Work Plan recommended that capability (i.e., column tests) at three different pH ranges (i.e., pH 3 to 4, pH 6 to 7, and pH 9 to 10) be performed. However, it was decided that column experiments using the natural pH (7 to 8) of the groundwater were more realistic for groundwater remediation studies at RFETS.

4.0 RESULTS AND DISCUSSION

4.1 DATA ANALYSIS AND INTERPRETATION

4.1.1 Uranium and Selenium (Wells GW3086 and B206789)

4.1.1.1 Column Experiments – Uranium and selenium results of column experiments for the nine ion-exchange resins are shown in Table 4.1.1.1-1. The data for pHs, TSS, TDS, metals, anions, and radionuclides determined by Accu-Labs Research, Inc. are shown in Appendix A. The uranium concentration in the feed solution (influent) was 105 μg/L (35 pCi/L), while the effluent concentrations range from 0.02 to 100 μg/L. The selenium concentration in the feed solution was 300 μg/L, while the effluent levels ranged from <5 to 300 μg/L.

Table 4.1.1.1-1 Ion-Exchange Experiments (Columns)

		Uranium-238**				Selenium*	
		EFF (ug/l)					
Ion Exchange Resin	Resin Type	(a)	(b)	INF/EFF	pH*	EFF (ug/l)	INF/EFF
Amberlite 200C	Strong Acid Cation	97	100	1.0	8.5	310	1.0
Amberlite DP-1	Weak Acid Cation	0.10	0.04	2620	9.7	290	1.0
Amberlite IRC-718	Metals Chelating	0.06	0.04	2620	10.5	300	1.0
Amberlite IRA-938	Strong Base Anion	0.10	0.02	5250	8.0	33	9.1
Purolite A-400	Strong Base Anion	0.02	0.05	2100	7.7	<5	>60
Ionac A-642	Strong Base Anion	0.01	0.03	3500	7.8	<5	>60
Dowex 21K	Strong Base Anion	0.03	0.02	5250	7.9	<5	>60
Diaion PA-308	Strong Base Anion	0.03	0.04	2620	8.2	<5	>60
Diaion CR-11	Metals Chelating	0.08	0.03	3500	10.2	290	1.0

Feed Solution = GW 3086 (50%) and GW B206789 (50%)
U-238 = 105 ug/l (35 pCi/l) and Se = 300 ug/l; pH 7.7

Column = 2.5 cm diamter x 15 cm height; Flow Rate = 1.5 to 2.0 ml/min

Volume Passed = 3.0 liters; Residence Time = 20 to 30 minutes

(a) Uranium Values from Accu-Labs Research, Inc. – (b) Uranium values from EG&G.

*pH and Selenium Values from Accu-Labs Research, Inc.

**Uranium Values Used for INF/EFF Ratios are from EG&G

Uranium values of EG&G generally agree with those of Accu-Lab Research, Inc. However, for consistency, the EG&G uranium values were used throughout the discussion. The RFs ranged from approximately 1 to 5250 for uranium. The RFs for selenium ranged from 1 to >60, based on influent value of 300 µg/L and effluent values of <5 µg/L. A higher RF value reflected a greater retention or removal of uranium or selenium by the resin. The RF of 1 for Amberlite 200C (strong acid cation) indicated that uranium and selenium were not retained in the column. It further suggested that uranium and selenium were not in cationic form in groundwater.

The RFs for uranium removal were very high (2100 to 5250) for the other eight resins. The effluent uranium concentrations were so close to the detection limit of the uranium analyzer (KPA-11) that they are expressed as one significant figure (See Table 4.1.1.1-1). The selenium value of <5 µg/L was also at the detection limit specified by GFAA.

Among the eight favorable resins for uranium removal, the metals chelating type (Amberlite IRC-718 and Diaion CR-11) and the weak acid cation type (Amberlite DP-1) showed high effluent pH values (9.7 to 10.7). Furthermore, these resin types showed no retention for selenium (See Table 4.1.1.1-1), thus making them less attractive for this application.

However, the strong base anion types showed no change in the effluent pH and had high RFs. These types also had a high retention for selenium (except Amberlite IRA-938) making them favorable ion-exchange resins for uranium and selenium removal. The effectiveness of the strong base anion type resins further suggested that uranium and selenium were present in an anionic form in groundwater. At pH 7 to 8, in an oxidizing environment, the anionic form for uranium may have been UO^{2--} and for selenium may have been SeO^{3--} or SeO^{4--} (Pourbaix, 1974).

The major cationic (i.e., Na, K, Mg, and Ca) and anionic (i.e., alkalinity, CO_3, HCO_3, Cl, NO_3, SO_4, and TDS) composition of the feedstock solution and the five favorable resin effluents are shown in Table 4.1.1.1-2. The concentrations of major cations Na, K, Mg, and Ca remained the same, which would be expected as the resins are similar to strong base anion. Thus, the exchange is expected with the anions. These resins are in chloride form of quarternary amine divinylbenzene/ styrene copolymer. The effluents showed considerable increase in chloride, while there was a considerable decrease in the nitrate and sulfate contents. Alkalinity remained the same, which was reflected in the same pH value. The TDS also remained the same at approximately 2200 mg/L.

Table 4.1.1.1-2 Major cation and anion composition mg/L (feed solution and ion-exchange effluents).

Analyte	Feed Solution	Amberlite IRA-938	Purolite A-400	Ionac A-642	Diaion PA-308	Dowex 21K
Sodium	410	400	400	390	410	400
Potassium	13	13	13	12	13	12
Magnesium	61	61	61	61	61	60
Calcium	150	180	170	170	160	150
Alkalinity	140	190	160	140	170	130
Carbonate	<5	<5	<5	<5	<5	<5
Bicarbonate	170	230	190	170	210	160
Chloride	97	500	1100	1100	950	1100
Nitrate	280	150	0.07	0.93	43	<0.05
Sulfate	400	220	<10	<10	<10	<10
TDS	2400	2000	2200	2100	2200	2200
pH	8.1	8.0	7.7	7.8	8.2	7.9

Four resins (i.e., Purolite A-400, Ionac A-642, Diaion PA-308, and Dowex 21K) show identical anionic concentrations relative to Amberlite IRA-938. The IRA-938 resin shows low chloride and high nitrate and sulfate contents, which indicates less capacity for an ionic exchange. The IRA-938 also shows less retention for selenium relative to the other four resins, which made IRA-938 less attractive in its application.

4.1.1.2 Batch Experiment for Uranium – Batch experiments provided information on the relative loading capacities and the nature of adsorption isotherms. Batch Kd is defined in Table 4.1.1.2-1.

Table 4.1.1.2-1 Batch Kd

$$\text{Batch Kd} = \frac{\text{Solid } (\mu g/g)}{\text{Liquid } (\mu g/ml)}$$

$$= \frac{\text{ml (Influent} - \text{Effluent)}}{\text{g (Effluent)}}$$

The batch Kd value was measured in units of ml/g. The batch Kd values for various resin weight to solution volume ratios (i.e., 1:50, 1:100, 1:200, and 1:400) for the five strong base anion resin types are shown in Tables 4.1.1.2-2 through 4.1.1.2-4: (1) Amberlite IRA-938, (2) Purolite A-400, (3) Ionac A-642, (4) Diaion PA-308, and (5) Dowex 21K. For comparison, the batch Kd values for one metal chelating resin type (Amberlite IRC-718) are shown in Table 4.1.1.2-4. The pH values of each of the resin weight solid to solution volume ratios are also included in these Tables. The pH values were fairly consistent (i.e., 7.9 to 8.1) among the varying solid to volume ratios. In the metal chelating resin type (Amberlite IRC-718), the pH (9.3) was high in 1:50 ratio. The pH then decreased to 8.4 for 1:100, 8.2 for 1:200, and 8.1 for the 1:400 ratios.

The 1:50 batch has very high influent/effluent ratio, which is approximately 10 to 50 times higher than the influent/ effluent ratios for 1:100, 1:200, and 1:400 solid to volume ratios. These high batch ratios are generally consistent with the column influent/effluent ratios (See Table 4.1.1.1-1), in which approximately 60 column volumes of the influent was passed through the column with a residence time of approximately 20 to 30 minutes. (The batch experiment involved approximately 24 hours residence time). This comparison suggests that equilibrium in the ion-exchange columns was easily reached in a very short residence time (i.e., 20 to 30 minutes).

The batch Kd values for the 1:100, 1:200, and 1:400 tests remained constant within a factor of 2. However, they generally decreased when the solution volume increased. This trend would be expected because there were more uranium atoms available in the solution for exchange, thus greater competition for the same ion-exchange sites. The mean batch Kd values for the various resins and their pH values are shown in Table 4.1.1.2-5.

Table 4.1.1.2-2 Ion-Exchange Experiments (Batch) for Uranium

Uranium-238 (μg/l)					
Resin Wt: Solution Vol	INF	EFF	INF/EFF	Batch Kd (ml/g)	pH
Amberlite IRA-938*					
1:50	105	0.02	5250	2.6×10^{5}**	8.1
1:100	105	1.8	58.3	5.7×10^{3}	8.1
1:200	105	5.6	18.7	3.5×10^{3}	8.1
1:400	105	12.5	8.4	3.0×10^{3}	8.1
			Mean	4.1×10^{3}	
Purolite A-400*					
1:50	105	0.06	1750	8.7×10^{4}**	8.1
1:100	105	1.4	75.0	7.4×10^{3}	8.1
1:200	105	3.9	26.9	5.2×10^{3}	8.1
1:400	105	9.2	11.4	4.2×10^{3}	8.1
			Mean	5.6×10^{3}	

*Strong Base Anion Resin (Quarternary Amine Divinylbenzene/Styrene Copolymer, Cl ion form)

**Not Included in the Mean

$$\text{Batch Kd} = \frac{\text{Solid } (\mu g/g)}{\text{Liquid } (\mu g/ml)}$$

Table 4.1.1.2-3 Ion-Exchange Experiments (Batch) for Uranium

Uranium-238 (µg/l)					
Resin Wt: Solution Vol	INF	EFF	INF/EFF	Batch Kd (ml/g)	pH
Ionac A-642*					
1:50	105	0.03	3500	1.7×10^{5}**	7.9
1:100	105	1.8	58.3	5.7×10^{3}	7.9
1:200	105	4.8	21.9	4.2×10^{3}	7.9
1:400	105	9.4	11.2	3.4×10^{3}	7.9
			Mean	4.6×10^{3}	
Diaion PA-308*					
1:50	105	0.04	2625	1.3×10^{5}**	7.9
1:100	105	1.6	65.6	6.5×10^{3}	7.9
1:200	105	4.4	23.8	4.6×10^{3}	7.9
1:400	105	9.8	10.7	3.9×10^{3}	7.9
			Mean	5.0×10^{3}	

*Strong Base Anion Resin (Quarternary Amine Divinylbenzene/Styrene Copolymer, Cl ion form)

**Not Included in the Mean

$$\text{Batch Kd} = \frac{\text{Solid } (\mu g/g)}{\text{Liquid } (\mu g/ml)}$$

Table 4.1.1.2-4 Ion-Exchange Experiments (Batch) for Uranium

Uranium-238 (µg/l)					
Resin Wt: Solution Vol	INF	EFF	INF/EFF	Batch Kd (ml/g)	pH
Dowex 21K*					
1:50	105	0.04	2625	1.3×10^{5}***	8.1
1:100	105	1.0	105	1.0×10^{4}	8.1
1:200	105	2.7	38.9	7.6×10^{3}	8.1
1:400	105	5.9	17.8	6.7×10^{3}	8.1
			Mean	8.1×10^{3}	
Amberlite IRC-718**					
1:50	105	0.05	2100	1.0×10^{5}***	9.3
1:100	105	0.84	125	1.2×10^{3}	8.4
1:200	105	2.0	52.5	1.0×10^{3}	8.2
1:400	105	10.3	10.2	3.7×10^{3}	8.1
			Mean	8.5×10^{3}	

*Strong Base Anion Resin (Quarternary Amine Divinylbenzene/Styrene Copolymer, Cl ion form)

**Metal Chelating Resin (DVB/STY/Iminodiacetate Copolymer, Na^{+} ion form)

***Not Included in the Mean

$$\text{Batch Kd} = \frac{\text{Solid } (\mu g/g)}{\text{Liquid } (\mu g/ml)}$$

Table 4.1.1.2-5 Ion-Exchange Experiments (Batch) for Uranium

Uranium-238 (μg/l)		
Resin	Mean Batch Kd (ml/g)	pH
Amberlite IRA-938 (Rohm and Haas Co.)	4.1×10^3	8.1
Purolite A-400 (Purolite Company)	5.1×10^3	8.1
Ionac A-642 (Sybron Chemical Co.)	4.6×10^3	7.9
Diaion PA-308 (Mitsubishi Kasei Corp)	5.0×10^3	8.1
Mean	4.8×10^3	
Dowex 21K (Dow Chemical Co.)	8.1×10^3	8.1

Strong Base Anion Resin (Quarternary Amine Divinylbenzene/Styrene Copolymer, Cl ion form)

$$\text{Batch Kd} = \frac{\text{Solid } (\mu g/g)}{\text{Liquid } (\mu g/ml)}$$

The mean batch Kd values for the four strong base anion resin types were nearly the same, except for Dowex-21K. A strong base anion resin type is a synthetic product of a quaternary amine divinylbenzene/styrene copolymer, chloride ion form. The copolymer group may have differed depending on the manufacturer, yet the mean batch Kd values of these synthetic resin were virtually identical. The mean value of these mean batch Kd values was 4.8×10^3 ml/g which indicates uranium removal to greater than 99.9 percent from groundwater.

The Dowex 21K resin was manufactured by Dow Chemical Company and the mean batch Kd value was 8.1×10^3 ml/g, approximately 70 percent better than the other four resins. The Amberlite IRC-718 (metal chelating) resin also had a high mean batch Kd value of 8.5×10^3 ml/g. However, due to high effluent pH (10.7) and no retention for selenium, the Amberlite IRC-718 was less attractive in its application. Overall, Dowex 21K appeared to be the best ion-exchange resin tested relative to the others.

Isotherm models such as linear and non-linear by Langmuir, Freundlich, and Modified Langmuir had been used to describe equilibrium relationships in adsorption or exchange processes (Sparito, 1980; Polzer et al, 1985; 1992). The following equation represents a linear isotherm.

$$\underset{\text{(Concentration)}}{\text{Solid (ug/g)}} = \text{Kd} \times \underset{\text{(Concentration)}}{\text{Liquid (ug/mL)}}$$

If the uranium concentration in the solid (µg/g) was plotted against the uranium concentration in the liquid (µg/ml), then the slope of a line would yield the batch Kd value. The uranium concentration adsorbed on the solid (µg/g) versus the uranium concentration left in the solution (µg/ml) for six resins are plotted in Figures 4.1.1.2-1 and 4.1.1.2-2.

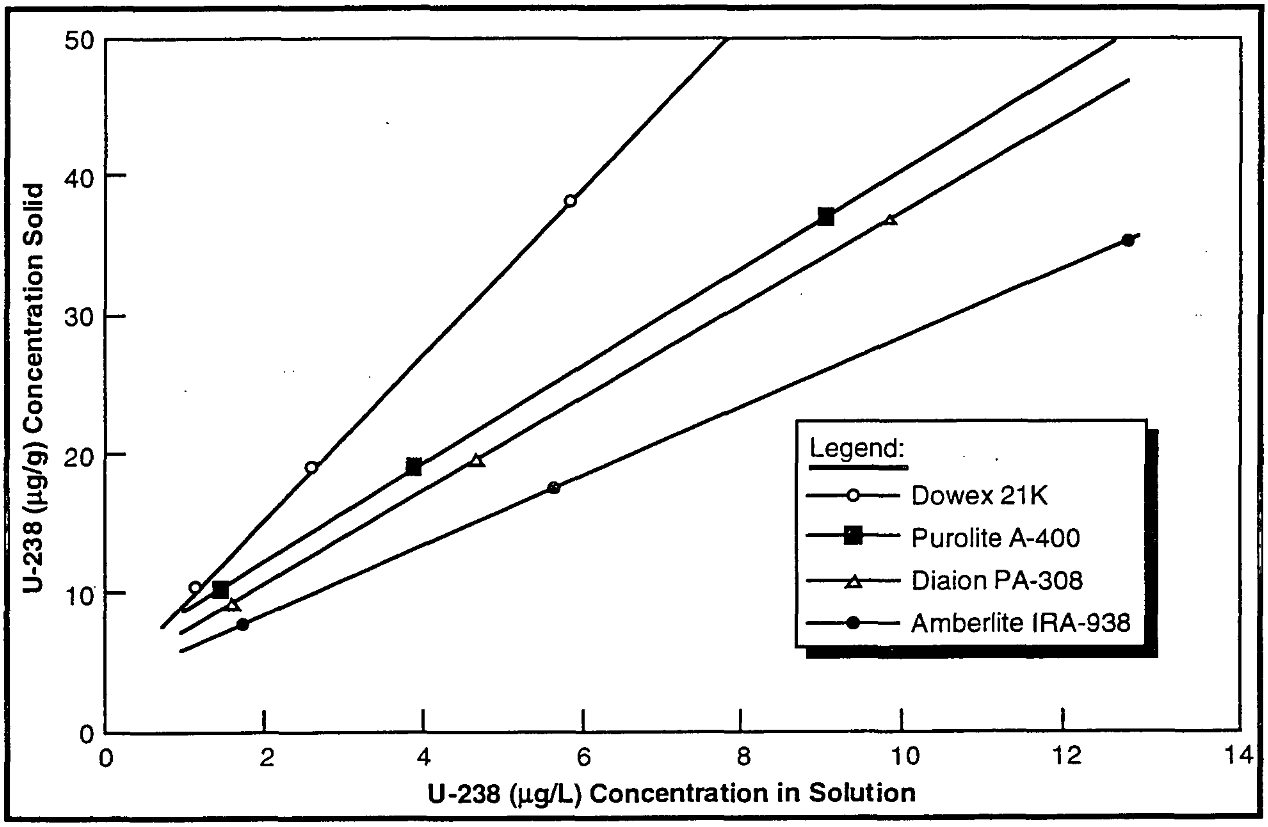

Figure 4.1.1.2-1 Uranium Isotherms for Strong Base Anion Resins

It is obvious that the strong base anion resin types exhibit a linear isotherm. A slope such as this will yield a batch Kd value at equilibrium which is similar to the mean batch Kd value shown in Table 4.1.1.2-5. Amberlite IRC-718 (metal chelating) showed a non-linear isotherm at the higher ratio, which may follow a Langmuir, Fruendlich, or modified Langmuir isotherm (Sparito, 1980; Polzer et al, 1985; 1992).

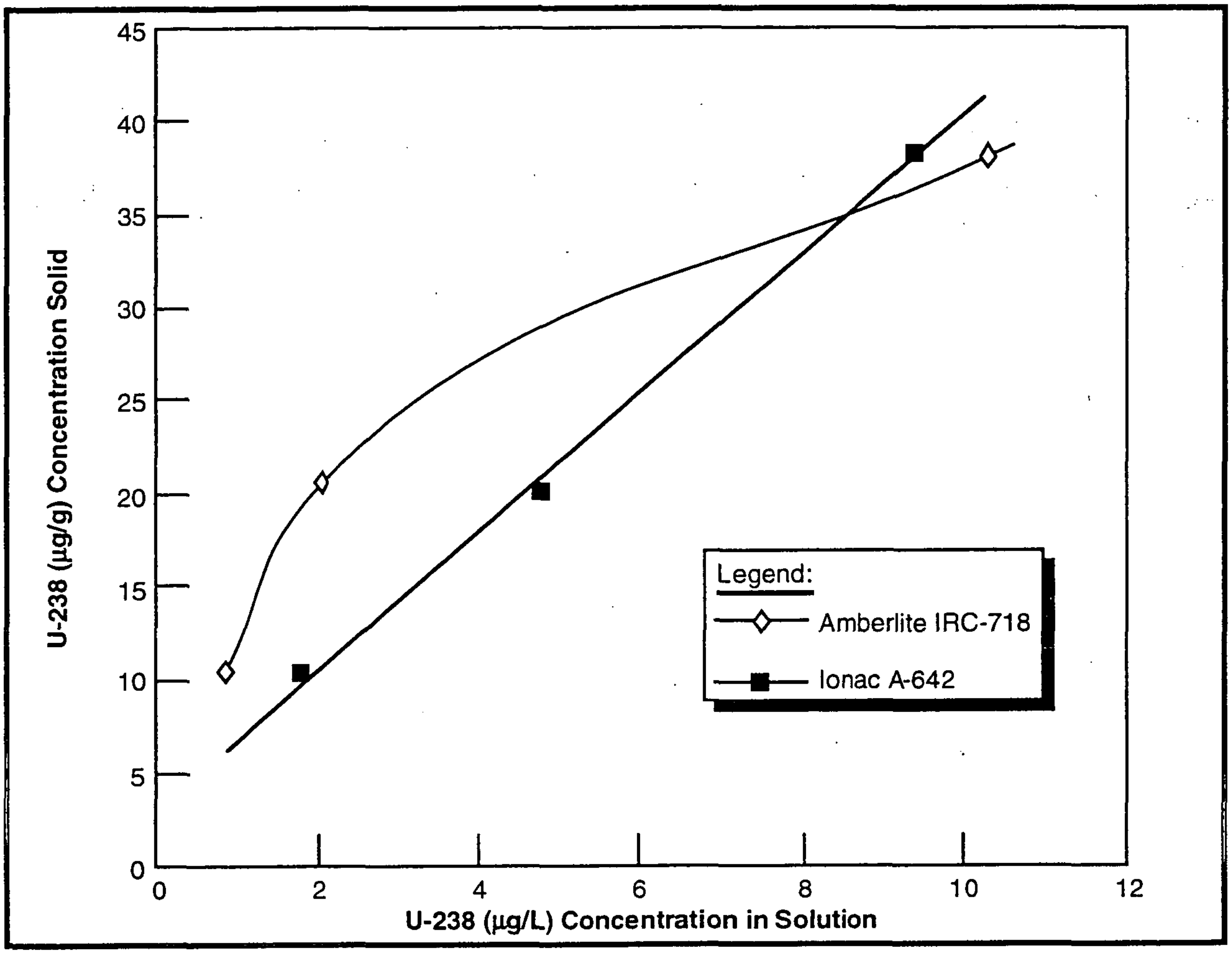

Figure 4.1.1.2-2 Uranium Isotherms for Strong Base Anion and Metal Chelating Resins

The ion-exchange resins could be regenerated and reused which could maximize their use and minimize their costs and generation of secondary wastes. A strong base anion resin type could be regenerated by washing the column with 10 percent hydrochloric acid (HCl), rinsing with water, and then washing with 4 percent sodium hydroxide (NaOH), or washing with brine (NaCl) solution. The regeneration and re-performance tests were not conducted in this treatability study.

These studies should be performed as part of the remedy selection for the Remedy Design Treatability Study.

4.1.1.3 Batch Experiments for Selenium – Based on the column experiments (See Table 4.1.1.1-1), four effective strong base anion resins for selenium removal were (1) Purolite A-400, (2) Ionac A-642, (3) Diaion PA-308, and (4) Dowex-21K. The results for the batch Kd value tests for selenium removal at resin weight to solution volume ratios of 1:50, 1:100, 1:200, and 1:400 are shown in Tables 4.1.1.3-1 and 4.1.1.3-2. The pH range remained constant (i.e., 7.9 to 8.1) among the various resin weights to solution volume ratios.

There was a gradual decrease in the batch Kd values from the 1:50 to 1:100 ratios. The batch Kd values then level off at approximately 170 ml/g for the 1:200 and 1:400 ratios. For three resins (i.e., Purolite A-400, Ionac A-642, and Diaion PA-308), the batch Kd values were nearly the same, and they leveled off around 170 ml/g, which was the batch Kd value for selenium for these three resins. Dowex-21K had somewhat higher batch Kd values and they leveled off at approximately 220 ml/g. It was approximately 30 percent more effective than the other three resins.

The isotherms of solid (µg/g) versus solution (µg/ml) of selenium for the four resins are shown in Figure 4.1.1.3-1. The isotherms are nearly linear. Selenium was measured using GFAA using a single injection of 0.020 ml. The results may have an error of 10 to 20 percent.

4.1.2 Analysis of Water Characteristics

Well GW3086 contained 66.7 pCi/L (200 mg/L) of uranium (U-238). Pu-239 +240 and Am-241 concentrations were below the potential ARAR value of 0.05 pCi/L. The COC (i.e., Be, Cr, Fe, Pb, Mn, Hg, and Se) were also below the potential ARAR values. The water samples' major cationic and anionic compositions and TDS (mg/L) are shown in Table 4.1.2.1-1. The pH was 7.6 which indicated a predominance of a bicarbonate medium.

Well B206789 contained uranium, plutonium, and americium below their potential ARARs. The COC (i.e., Be, Cr, Fe, Pb, Mn, and Hg) were also below the potential ARARs (See Appendix A). Only selenium was above its potential ARAR value of 10 µg/L with a concentration of 600 µg/L.

The major cationic and anionic compositions are shown in Table 4.1.2.1-1. This water contained three times less TDS (1200 mg/L) in Well GW3086 (3800 mg/L), which was also reflected in lower cationic and anionic composition (See Section 1.2.1). The pH was 7.8 which indicated predominance of bicarbonate medium.

Table 4.1.1.3-1 Ion-Exchange Experiments (Batch) for Selenium

Selenium (µg/l)					
Resin Wt: Solution Vol	INF	EFF	INF/EFF	Batch Kd (ml/g)	pH
Purolite A-400*					
1:50	300	36.9	8.1	356	8.1
1:100	300	85.7	3.5	250	8.1
1:200	300	155	1.9	187	8.1
1:400	300	210	1.4	171	8.1
1:400**	300	210	1.4	171	7.4
Ionac A-642*					
1:50	300	32.9	9.1	406	7.9
1:100	300	85.5	3.5	250	7.9
1:200	300	161	1.9	173	7.9
1:400	300	211	1.4	169	7.9
1:400**	300	230	1.3	122	7.9

*Strong Base Anion Resin (Quarternary Amine Divinylbenzene/Styrene Copolymer, Cl ion form)

**Data from Accu-Labs Research, Inc.

$$\text{Batch Kd} = \frac{\text{Solid } (\mu g/g)}{\text{Liquid } (\mu g/ml)}$$

Table 4.1.1.3-2 Ion-Exchange Experiments (Batch) for Selenium

Selenium (µg/l)					
Resin Wt: Solution Vol	INF	EFF	INF/EFF	Batch Kd (ml/g)	pH
Diaion PA-308*					
1:50	300	39.1	7.7	334	8.1
1:100	300	97	3.01	209	8.1
1:200	300	166	1.8	161	8.1
1:400	300	211	1.4	169	8.1
1:400**	300	220	1.9	145	8.0
Dowex 21K*					
1:50	300	28.8	10.4	470	8.1
1:100	300	68	4.4	341	8.1
1:200	300	140	2.1	228	8.1
1:400	300	193	1.5	222	8.1
1:400*	300	210	1.4	171	7.8

*Strong Base Anion Resin (Quarternary Amine Divinylbenzene/Styrene Copolymer, Cl ion form)

**Data from Accu-Labs Research, Inc.

$$\text{Batch Kd} = \frac{\text{Solid } (\mu g/g)}{\text{Liquid } (\mu g/ml)}$$

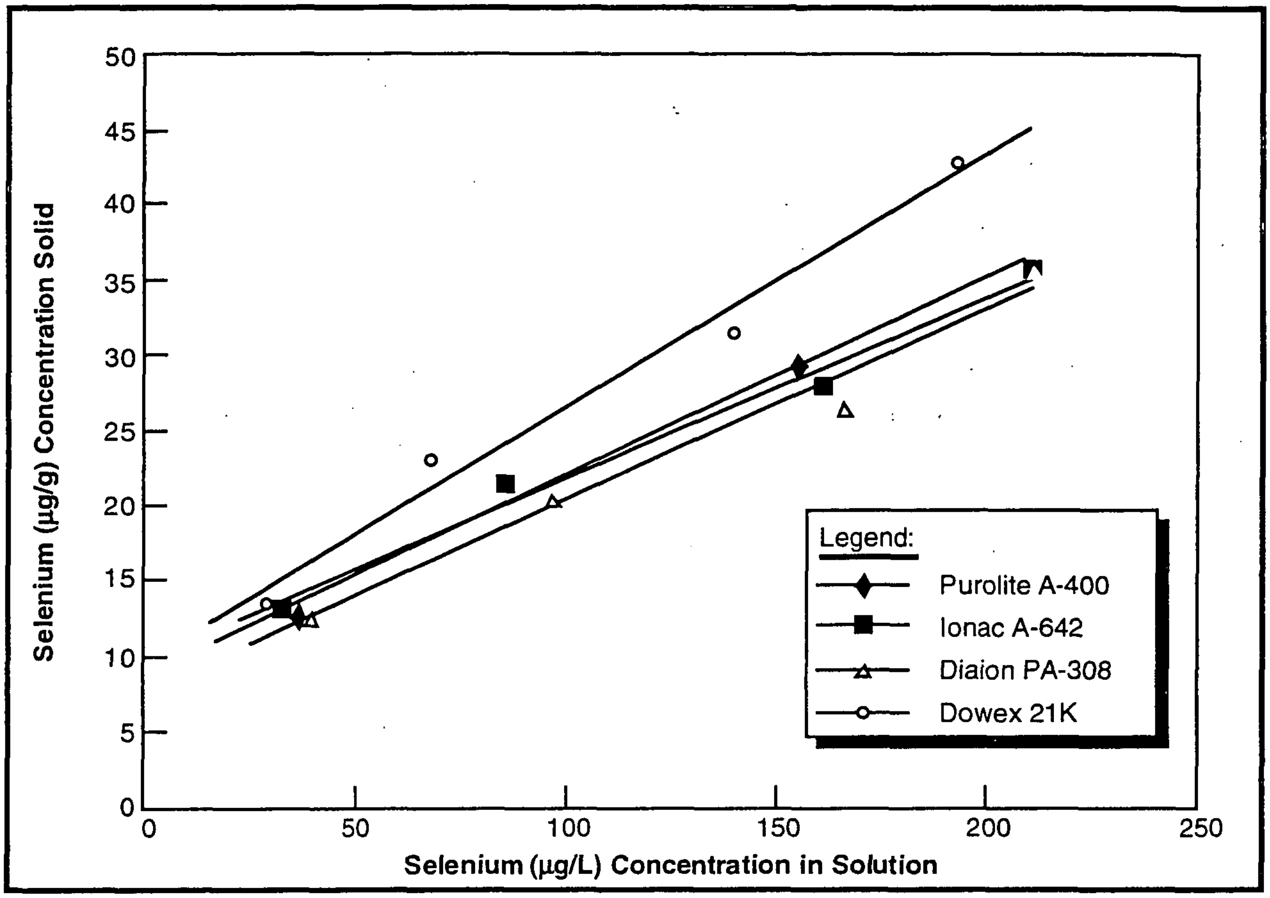

Figure 4.1.1.3-1 Selenium Isotherms for Strong Base Anion Resins

Groundwater samples from Wells GW3086 and B206789 were filtered through a 0.45 µm medium and then combined in equal proportions for the feed solution. The uranium and selenium concentrations in the feed solution were 105 µg/L (35 pCi/L) and 300 µg/L, respectively. The other COC were below their potential ARARs in the feed solution. The TDS, cationic, and anionic compositions reflected the mixing of two waters. The pH of feed solution was 7.7.

4.1.3 Analysis of Treatability Study Data

The experiments focused on the removal of uranium and selenium from the feed solution by the nine ion-exchange resins using column and batch tests. If a column test proved ineffective for selenium removal (i.e., no retention), then no batch test was performed for that particular resin.

For uranium, eight resins showed strong retention, however, batch experiments were performed for only five strong base anion resin types and one metal chelating resin type.

The influent/effluent ratios for uranium were very high and comparable in the column and 1:50 ratio batch tests. This indicated that the equilibration was reached in a very short time (i.e., 20 to 30 minutes). The batch Kd values and ion-exchange isotherm plots of solid (μg/g) versus liquid (μg/L) were used to establish a linear or non-linear relationship. For the strong base anion resin types, the uranium and selenium isotherms were linear (See Figs 4.1.1.2-1, 4.1.1.2-2, and 4.1.1.3-1). These tests were important in the evaluation of the loading capacities and breakthrough in a field demonstration.

4.1.4 Comparison to Test Objectives

Comparison of results (See Tables 4.1.1.2-1 to 4.1.1.2-5 and 4.1.1.3-1 and 4.1.1.3-2) clearly show that eight ion-exchange resins are favorable for the effective removal of uranium. However, among the various types, strong base anion resin types appear to be the most suitable with a mean batch Kd value of 4.8×10^3 ml/g. This indicates an effective removal of uranium greater than 99.9 percent. Dowex 21K resin, also a strong base anion type, is approximately 70 percent more efficient than the other resins tested.

For selenium removal, four strong base anion resin types are effective. Three resins show a mean batch Kd value of approximately 170 ml/g, while Dowex 21K has a mean batch Kd value of 220 ml/g and is approximately 30 percent more efficient than the other resins tested. Retentions by the strong base anion resin type suggest that uranium and selenium were present in an ionic form in the RFETS groundwater.

Based on the batch Kd values, uranium removal is 30 to 40 times more effective than selenium removal by the strong base anion resin types. Overall, Dowex 21K is the best resin relative to the others tested. Overall, these resins were effective in removing uranium and selenium to concentrations below their respective potential ARARs (15 μg/L or 5 pCi/L for uranium and 10 μg/L for selenium) in column and batch experiments.

4.2 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

All the experiments used the same homogeneous feed solution, which avoided any variability in the sampling procedure. The operating parameters such as flow rate, effluent volume, column dimension, volume used for batch tests, tumbling speed, and equilibration time were kept constant to minimize any variability in these parameters. For internal analyses, calibrated standards covering the desired range of concentrations were used for measurements of pH, uranium, and selenium. Duplicate analyses were performed for some tests to determine the error which was approximately 10 percent for uranium removal and 10 to 20 percent for selenium removal. QA/QC Level II was used in intermediate and final analysis of samples at EG&G. Confirmation of some final results were obtained from Accu-Labs Research, Inc. using QA/QC Level III.

The samples were also analyzed by Accu-Labs Research, Inc., an EPA certified lab, for complete characterization of analytes such as pH, TSS, TDS, metals, anions, and radionuclides. All the results reported in this report can be tracked and verified through EG&G and Accu-Labs Research, Inc.

4.3 COSTS FOR TREATABILITY STUDY

A Work Plan was written and approved by DOE, CDH, and EPA to support this treatability study. Following its approval, the work was initiated. It included: (1) water sampling (2 weeks), (2) ordering equipment and performing the column and batch experiments (12 weeks), (3) analysis of various analyte pH values, TDS, TSS, metals, anions, and radionuclides (i.e., U-234, U-238, Pu-239+240, and Am-241) by Accu-Labs Research, Inc. (12 weeks), and (4) data reduction and a written report (6 weeks). This study lasted approximately 10 months and cost approximately $130,000.

Table 4.3-1 lists the costs of the various resins by their manufacturers. The costs range between $125/ft^3 to $725/ft^3. For strong base anion resin types, the costs range from $150/ft^3 to $725/ft^3. For the Dowex 21K resin, the most effective resin tested, the cost is approximately $178/ft^3 and it is readily available. This resin can be regenerated and reused a number of times to maximize its use. This is cost-effective in the long run, and can minimize waste problems because of regeneration of the resin and stripping of metals and radionuclides.

Table 4.3-1 Cost and Availability of Resins

Manufacturer	Resin	Cost	Availability
Rohm & Haas Co.	Amberlite IRC-718	$420/ft^3	2 – 12 Weeks
Rohm & Haas Co.	Amberlite 200C	$125/ft^3	Depends on Quantity
Rohm & Haas Co.	Amberlite DP-1	$160/ft^3	Depends on Quantity
Rohm & Haas Co.	Amberlite IRA-938	$725/ft^3	2 – 12 Weeks
Mitsubishi Kasei Corp.	Diaion CR-11	$425/ft^3	Readily Available
Mitsubishi Kasei Corp.	Diaion PA-308	$280/ft^3	Readily Available
Purolite Company	Purolite A-400	$150/ft^3	Readily Available
Sybron Chemical Co.	Ionac A-642	$222/ft^3	Readily Available
Dow Chemical Co.	Dowex 21K	$178/ft^3	Readily Available

4.4 KEY CONTACTS

The key contacts for this report are:

J.C. Laul
Environmental Technologies
EG&G RFETS
Building 881
Golden CO 80402
Phone 303-966-3254

M.C. Rupert
Environmental Engineering and Technology
Environmental Restoration
EG&G RFETS
Building 080
Golden CO 80402
Phone 303-966-6956

5.0 REFERENCES

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Appendix A

Analytical Data from Accu-Labs Research, Inc., Golden, Colorado

Accu-Labs® Research, Inc.
663 Table Mountain Drive Golden, Colorado 80403-1650
(303) 277-9514 FAX (303) 277-9512

ANALYSIS REPORT

DATE: 06/09/94 PAGE 1

J.C. LAUL
EG&G ROCKY FLATS, INC.
ROCKY FLATS PLANT
P.O. BOX 464, BLDG 080
GOLDEN, CO 80402-0464

Lab Job Number: 2426-54257-8
Date Samples Received: 05/13/94
Customer PO Number: ASC233268J03

These samples will be disposed of 30 days after the date of this report.

ALR Designation -	2426-54257-8-1	2426-54257-8-2
Sponsor Designation -	3086-UNFIL	3086-FIL
Date Collected -	04/19/94	04/19/94

Determinations in pCi/L unless noted

Uranium-234 - dissolved	--N/A--	140 ± 10
Uranium-234 - total	120 ± 20	--N/A--
Uranium-238 - dissolved	--N/A--	90 ± 10
Uranium-238 - total	78 ± 13	--N/A--
Plutonium-239+240 - dissolved	--N/A--	0.01 ± 0.02
Plutonium-239+240 - total	0.00 ± 0.01	--N/A--
Americium-241 - dissolved	--N/A--	-0.01 ± 0.03
Americium-241 - total	-0.01 ± 0.03	--N/A--
Uranium - dissolved (mg/L)	--N/A--	0.19
Uranium - dissolved (rerun) (mg/L)	--N/A--	--N/A--
Uranium - total (mg/L)	0.20	--N/A--

Accu-Labs® Research, Inc.
663 Table Mountain Drive Golden, Colorado 80403-1650
(303) 277-9514 FAX (303) 277-9512

ANALYSIS REPORT

DATE: 06/01/94 PAGE 1

J.C. LAUL
EG&G ROCKY FLATS, INC.
ROCKY FLATS PLANT
P O BOX 464 BLDG 080
GOLDEN, CO 80402-0464

Lab Job Number: 2426-54257-8
Date Samples Received: 05/13/94
Customer PO Number: ASC233268J03

These samples to be disposed of 30 days after the date of this report.

ALR Designation -	2426-54257-8-1	2426-54257-8-2
Sponsor Designation -	3086-UNFIL	3086-FIL
Date Collected -	04/19/94	04/19/94
Determinations in mg/L unless noted		
Silver - dissolved	----	<0.005
Silver - total	<0.005	----
Aluminum - dissolved	----	<0.1
Aluminum - total	3.8	----
Barium - dissolved	----	0.07
Barium - total	0.08	----
Beryllium - dissolved	----	<0.005
Beryllium - total	<0.005	----
Calcium - dissolved	----	290
Calcium - total	260	----
Cadmium - dissolved	----	<0.005
Cadmium - total	<0.005	----
Cobalt - dissolved	----	<0.005
Cobalt - total	<0.005	----
Chromium - dissolved	----	<0.005
Chromium - total	0.011	----
Copper - dissolved	----	<0.005
Copper - total	0.005	----
Iron - dissolved	----	<0.01
Iron - total	1.6	----
Potassium - dissolved	----	31
Potassium - total	39	----
Lithium - dissolved	----	0.63
Lithium - total	0.58	----
Magnesium - dissolved	----	83

ANALYSIS REPORT
DATE: 06/01/94 PAGE 2
Lab Job Number 2426-54257-8

These samples to be disposed of 30 days after the date of this report.

ALR Designation -	2426-54257-8-1	2426-54257-8-2
Sponsor Designation -	3086-UNFIL	3086-FIL
Date Collected -	04/19/94	04/19/94
Determinations in mg/L unless noted		
Magnesium - total	76	----
Manganese - dissolved	----	<0.005
Manganese - total	0.013	----
Molybdenum - dissolved	----	<0.01
Molybdenum - total	0.01	----
Sodium - dissolved	----	650
Sodium - total	630	----
Nickel - dissolved	----	<0.02
Nickel - total	<0.02	----
Antimony - dissolved	----	<0.05
Antimony - total	<0.05	----
Thallium - dissolved	----	<0.1
Thallium - total	0.1	----
Vanadium - dissolved	----	<0.005
Vanadium - total	0.007	----
Zinc - dissolved	----	<0.005
Zinc - total	0.008	----
Alkalinity, Total (as CaCO3 to pH 4.5)	400	320
Carbonate (as CO3)	<5	<5
Bicarbonate (as HCO3)	480	390
pH (pH Units)	7.7	7.5
Arsenic - dissolved	----	<0.005
Arsenic - total	<0.005	----
Mercury - dissolved	----	<0.0001
Mercury - total	0.0001	----
Lead - dissolved	----	<0.005
Lead - total	<0.005	----
Selenium - dissolved	----	<0.005
Selenium - total	<0.005	----
Nitrate (as N)	510	560

ANALYSIS REPORT

DATE: 06/01/94 PAGE 3

Lab Job Number 2426-54257-8

These samples to be disposed of 30 days after the date of this report.

ALR Designation -	2426-54257-8-1	2426-54257-8-2
Sponsor Designation -	3086-UNFIL	3086-FIL
Date Collected -	04/19/94	04/19/94
Determinations in mg/L unless noted		
Total Dissolved Solids (@180 °C)	3,800	4,000
Total Suspended Solids (@105 °C)	74	----
Chloride	110	120
Sulfate (as SO4)	220	230

Accu-Labs® Research, Inc.
Table Mountain Drive Golden, Colorado 80403-1650
277-9514 FAX (303) 277-9512

ANALYSIS REPORT

DATE: 08/24/94 PAGE 1

J.C. LAUL
EG&G ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
P O BOX 464 BLDG 080
GOLDEN, CO 80402-0464

Lab Job Number: 2426-55335-12
Date Samples Received: 07/07/94
Customer PO Number: ASC233268JO3

These samples to be disposed of 30 days after the date of this report.

ALR Designation -	2426-55335-12-1	2426-55335-12-2	2426-55335-12-3	2426-55335-12-4
Sponsor Designation -	B206789	B206789	FEED SOLUTION	200C
Comments -	UNFILTERED	FILTERED		
Date Collected -				
Determinations in pCi/Filter Comp. unless noted				
Uranium-234 - dissolved (pCi/L)	----	3.3 ± 1.1 *	43 ± 2 *	43 ± 5 *
Uranium-234 - total (pCi/L)	2.6 ± 0.4 *	----	----	----
Uranium-238 - dissolved (pCi/L)	----	1.3 ± 0.7 *	29 ± 1 *	29 ± 4 *
Uranium-238 - total (pCi/L)	2.0 ± 0.3 *	----	----	----
Plutonium-239+240 - dissolved (pCi/L)	----	-0.02±0.05 *	-0.01±0.06 *	----
Plutonium-239+240 - total (pCi/L)	-0.03±0.05 *	----	----	----
Americium-241 - dissolved (pCi/L)	----	0.01 ± 0.04 *	0.00 ± 0.02 *	----
Americium-241 - total (pCi/L)	0.01 ± 0.02 *	----	----	----
Uranium by KPA - total (µg/L)	4.7	4.4	97	97

ANALYSIS REPORT

DATE: 08/24/94 PAGE 2

Lab Job Number 2426-55335-12

These samples to be disposed of 30 days after the date of this report.

ALR Designation -	2426-55335-12-5	2426-55335-12-6	2426-55335-12-7	2426-55335-12-8
Sponsor Designation -	DP-1	718	938	A-400
Comments -				
Date Collected -				
Determinations in pCi/Filter Comp. unless noted				
Uranium-234 - dissolved (pCi/L)	----	0.1 ± 0.2 *	0.1 ± 0.1 *	0.0 ± 0.1 *
Uranium-238 - dissolved (pCi/L)	----	0.0 ± 0.1 *	0.0 ± 0.1 *	0.0 ± 0.1 *
Uranium by KPA - total (µg/L)	0.10	0.06	0.10	0.02

ALR Designation -	2426-55335-12-9	2426-55335-12-10	2426-55335-12-11	2426-55335-12-12
Sponsor Designation -	A-642	DOWEX 21K	PA 308	CR-11
Comments -				
Date Collected -				
Uranium by KPA - total (µg/L)	0.01	0.03	0.03	0.08

* Variability of the radioactive disintegration process (counting error) at the 95% confidence level, 1.96σ.

By: [signature]
Bud Summers
Radiochemistry Supervisor

BS/dh

Accu-Labs® Research, Inc.

4663 Table Mountain Drive Golden, Colorado 80403-1650
[illegible] 277-9514 FAX (303) 277-9512

ADDITIONAL INFORMATION

ANALYSIS REPORT

DATE: 08/19/94 PAGE 1

J.C. LAUL
EG&G ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
P O BOX 464 BLDG 080
GOLDEN, CO 80402-0464

Lab Job Number: 2426-55335-12
Date Samples Received: 07/07/94
Customer PO Number: ASC233268JO3

These samples to be disposed of 30 days after the date of this report.

ALR Designation -	2426-55335-12-1	2426-55335-12-2	2426-55335-12-3	2426-55335-12-4
Sponsor Designation -	B206789	B206789	FEED SOLUTION	200C
Comments -	UNFILTERED	FILTERED		
Date Collected -				
Determinations in mg/L unless noted				
Silver - dissolved	----	<0.005	<0.005	<0.005
Silver - total	<0.005	----	----	----
Aluminum - dissolved	----	<0.1	<0.1	<0.1
Aluminum - total	0.3	----	----	----
Barium - dissolved	----	<0.05	<0.05	<0.05
Barium - total	<0.05	----	----	----
Beryllium - dissolved	----	<0.005	<0.005	<0.005
Beryllium - total	<0.005	----	----	----
Calcium - dissolved	----	160	150	0.2
Calcium - total	150	----	----	----
Cadmium - dissolved	----	<0.005	<0.005	<0.005
Cadmium - total	<0.005	----	----	----
Cobalt - dissolved	----	<0.005	<0.005	<0.005
Cobalt - total	<0.005	----	----	----
Chromium - dissolved	----	<0.005	<0.005	<0.005
Chromium - total	<0.005	----	----	----
Copper - dissolved	----	<0.005	<0.005	<0.005
Copper - total	<0.005	----	----	----
Iron - dissolved	----	0.01	<0.01	0.02
Iron - total	0.30	----	----	----
Potassium - dissolved	----	3.6	13	1.0
Potassium - total	3.3	----	----	----
Lithium - dissolved	----	0.22	0.39	0.09
Lithium - total	0.20	----	----	----
Magnesium - dissolved	----	44	61	<0.05

ANALYSIS REPORT
DATE: 08/19/94 PAGE 2
Lab Job Number 2426-55335-12

These samples to be disposed of 30 days after the date of this report.

ALR Designation -	2426-55335-12-1	2426-55335-12-2	2426-55335-12-3	2426-55335-12-4
Sponsor Designation -	B206789	B206789	FEED SOLUTION	200C
Comments -	UNFILTERED	FILTERED		
Date Collected -				
Determinations in mg/L unless noted				
Magnesium - total	41	----	----	----
Manganese - dissolved	----	<0.005	<0.005	<0.005
Manganese - total	0.007	----	----	----
Molybdenum - dissolved	----	<0.01	<0.01	<0.01
Molybdenum - total	<0.01	----	----	----
Sodium - dissolved	----	140	410	720
Sodium - total	130	----	----	----
Nickel - dissolved	----	<0.02	<0.02	<0.02
Nickel - total	<0.02	----	----	----
Antimony - dissolved	----	<0.05	<0.05	<0.05
Antimony - total	<0.05	----	----	----
Thallium - dissolved	----	<0.1	<0.1	0.1
Thallium - total	<0.1	----	----	----
Vanadium - dissolved	----	<0.005	<0.005	<0.005
Vanadium - total	<0.005	----	----	----
Zinc - dissolved	----	<0.005	<0.005	<0.005
Zinc - total	0.024	----	----	----
Alkalinity, Total (as $CaCO_3$ to pH 4.5)	180	180	140	250
Carbonate (as CO_3)	<5 [16]	<5 [16]	<5 [16]	<5 [16]
Bicarbonate (as HCO_3)	220 [16]	210 [16]	170 [16]	300 [16]
pH (pH Units)	8.0	7.9	8.1	8.5
Arsenic - dissolved	----	<0.005	<0.005	<0.005
Arsenic - total	<0.005	----	----	----
Mercury - dissolved	----	<0.0001	<0.0001	<0.0001
Mercury - total	<0.0001	----	----	----
Lead - dissolved	----	<0.005	<0.005	<0.005
Lead - total	<0.005	----	----	----
Selenium - dissolved	----	0.60	0.30	0.31
Selenium - total	0.66	----	----	----
Nitrate (as N)	6.8	6.7	280	290

Accu-Labs® Research, Inc.

ANALYSIS REPORT

DATE: 08/19/94 PAGE 2

Lab Job Number 2426-55335-12

These samples to be disposed of 30 days after the date of this report.

ALR Designation -	2426-55335-12-1	2426-55335-12-2	2426-55335-12-3	2426-55335-12-4
Sponsor Designation -	B206789	B206789	FEED SOLUTION	200C
Comments -	UNFILTERED	FILTERED		
Date Collected -				
Determinations in mg/L unless noted				
Magnesium - total	41	----	----	----
Manganese - dissolved	----	<0.005	<0.005	<0.005
Manganese - total	0.007	----	----	----
Molybdenum - dissolved	----	<0.01	<0.01	<0.01
Molybdenum - total	<0.01	----	----	----
Sodium - dissolved	----	140	410	720
Sodium - total	130	----	----	----
Nickel - dissolved	----	<0.02	<0.02	<0.02
Nickel - total	<0.02	----	----	----
Antimony - dissolved	----	<0.05	<0.05	<0.05
Antimony - total	<0.05	----	----	----
Thallium - dissolved	----	<0.1	<0.1	0.1
Thallium - total	<0.1	----	----	----
Vanadium - dissolved	----	<0.005	<0.005	<0.005
Vanadium - total	<0.005	----	----	----
Zinc - dissolved	----	<0.005	<0.005	<0.005
Zinc - total	0.024	----	----	----
Alkalinity, Total (as CaCO3 to pH 4.5)	180	180	140	250
Carbonate (as CO3)	<5 [16]	<5 [16]	<5 [16]	<5 [16]
Bicarbonate (as HCO3)	220 [16]	210 [16]	170 [16]	300 [16]
pH (pH Units)	8.0	7.9	8.1	8.5
Arsenic - dissolved	----	<0.005	<0.005	<0.005
Arsenic - total	<0.005	----	----	----
Mercury - dissolved	----	<0.0001	<0.0001	<0.0001
Mercury - total	<0.0001	----	----	----
Lead - dissolved	----	<0.005	<0.005	<0.005
Lead - total	<0.005	----	----	----
Selenium - dissolved	----	0.60	0.30	0.31
Selenium - total	0.66	----	----	----
Nitrate (as N)	6.8	6.7	280	290

Accu-Labs® Research, Inc.

ANALYSIS REPORT

DATE: 08/19/94 PAGE 3

Lab Job Number 2426-55335-12

These samples to be disposed of 30 days after the date of this report.

ALR Designation -	2426-55335-12-1	2426-55335-12-2	2426-55335-12-3	2426-55335-12-4
Sponsor Designation -	B206789	B206789	FEED SOLUTION	200C
Comments -	UNFILTERED	FILTERED		
Date Collected -				
Determinations in mg/L unless noted				
Total Dissolved Solids (@180 °C)	1,200	1,200	2,400	2,500
Total Suspended Solids (@105 °C)	18	----	----	----
Chloride	74	72	97	96
Sulfate (as SO4)	590	590	400	390

Accu-Labs® Research, Inc.

ANALYSIS REPORT

DATE: 08/19/94 PAGE 4

Lab Job Number 2426-55335-12

These samples to be disposed of 30 days after the date of this report.

ALR Designation -	2426-55335-12-5	2426-55335-12-6	2426-55335-12-7	2426-55335-12-8
Sponsor Designation -	DP-1	718	938	A-400
Comments -				
Date Collected -				
Determinations in mg/L unless noted				
Silver - dissolved	<0.005	<0.005	<0.005	<0.005
Aluminum - dissolved	<0.1	<0.1	<0.1	<0.1
Barium - dissolved	<0.05	<0.05	<0.05	<0.05
Beryllium - dissolved	<0.005	<0.005	<0.005	<0.005
Calcium - dissolved	11	0.2	180	170
Cadmium - dissolved	<0.005	<0.005	<0.005	<0.005
Cobalt - dissolved	<0.005	<0.005	<0.005	<0.005
Chromium - dissolved	<0.005	<0.005	<0.005	<0.005
Copper - dissolved	<0.005	<0.005	<0.005	<0.005
Iron - dissolved	<0.01	<0.01	<0.01	<0.01
[illegible]ssium - dissolved	12	14	13	13
Lithium - dissolved	0.02	0.14	0.40	0.38
Magnesium - dissolved	3.8	3.2	61	61
Manganese - dissolved	<0.005	<0.005	<0.005	<0.005
Molybdenum - dissolved	<0.01	<0.01	<0.01	<0.01
Sodium - dissolved	750	810	400	400
Nickel - dissolved	0.02	<0.02	<0.02	<0.02
Antimony - dissolved	<0.05	<0.05	<0.05	<0.05
Thallium - dissolved	<0.1	<0.1	<0.1	<0.1
Vanadium - dissolved	<0.005	<0.005	<0.005	<0.005
Zinc - dissolved	<0.005	<0.005	<0.005	<0.005
Alkalinity, Total (as CaCO3 to pH 4.5)	350	480	190	160
Carbonate (as CO3)	120 [16]	280 [16]	<5 [16]	<5 [16]
Bicarbonate (as HCO3)	180 [16]	24 [16]	230 [16]	190 [16]
pH				
(pH Units)	9.7	10.5	8.0	7.7
Arsenic - dissolved	<0.005	<0.005	<0.005	<0.005
Mercury - dissolved	<0.0001	<0.0001	<0.0001	<0.0001
Lead - dissolved	<0.005	<0.005	<0.005	<0.005
Selenium - dissolved	0.29	0.30	0.033	<0.005
Nitrate (as N)	280	300	150	0.07

ANALYSIS REPORT
DATE: 08/19/94 PAGE 5
Lab Job Number 2426-55335-12

These samples to be disposed of 30 days after the date of this report.

ALR Designation -	2426-55335-12-5	2426-55335-12-6	2426-55335-12-7	2426-55335-12-8
Sponsor Designation -	DP-1	718	938	A-400
Comments -				
Date Collected -				
Determinations in mg/L unless noted				
Total Dissolved Solids (@180 °C)	2,600	2,700	2,000	2,200
Chloride	98	100	500	1,100
Sulfate (as SO4)	400	400	220	<10

ANALYSIS REPORT
DATE: 08/19/94 PAGE 6
Lab Job Number 2426-55335-12

These samples to be disposed of 30 days after the date of this report.

ALR Designation -	2426-55335-12-9	2426-55335-12-10	2426-55335-12-11	2426-55335-12-12
Sponsor Designation -	A-642	DOWEX 21K	PA 308	CR-11
Comments -				
Date Collected -				
Determinations in mg/L unless noted				
Silver - dissolved	<0.005	<0.005	<0.005	<0.005
Aluminum - dissolved	<0.1	<0.1	<0.1	<0.1
Barium - dissolved	<0.05	<0.05	<0.05	<0.05
Beryllium - dissolved	<0.005	<0.005	<0.005	<0.005
Calcium - dissolved	170	150	160	1.0
Cadmium - dissolved	<0.005	<0.005	<0.005	<0.005
Cobalt - dissolved	<0.005	<0.005	<0.005	<0.005
Chromium - dissolved	<0.005	<0.005	0.005	<0.005
Copper - dissolved	<0.005	<0.005	<0.005	<0.005
Iron - dissolved	0.01	<0.01	<0.01	0.03
Potassium - dissolved	12	12	13	11
Lithium - dissolved	0.39	0.39	0.40	0.16
Magnesium - dissolved	61	60	61	<0.05
Manganese - dissolved	<0.005	<0.005	<0.005	<0.005
Molybdenum - dissolved	<0.01	<0.01	<0.01	<0.01
Sodium - dissolved	390	400	410	740
Nickel - dissolved	<0.02	<0.02	<0.02	0.03
Antimony - dissolved	<0.05	<0.05	<0.05	<0.05
Thallium - dissolved	0.1	0.1	<0.1	<0.1
Vanadium - dissolved	<0.005	<0.005	<0.005	<0.005
Zinc - dissolved	<0.005	<0.005	1.8	<0.005
Alkalinity, Total (as CaCO3 to pH 4.5)	140	130	170	330
Carbonate (as CO3)	<5 [16]	<5 [16]	<5 [16]	190 [16]
Bicarbonate (as HCO3)	170 [16]	160 [16]	210 [16]	<5 [16]
pH (pH Units)	7.8	7.9	8.2	10.2
Arsenic - dissolved	<0.005	<0.005	<0.005	<0.005
Mercury - dissolved	<0.0001	<0.0001	<0.0001	<0.0001
Lead - dissolved	<0.005	<0.005	<0.005	<0.005
Selenium - dissolved	<0.005	<0.005	<0.005	0.29
Nitrate (as N)	0.93	<0.05	43	270

ANALYSIS REPORT

DATE: 08/19/94 PAGE 7

Lab Job Number 2426-55335-12

These samples to be disposed of 30 days after the date of this report.

ALR Designation -	2426-55335-12-9	2426-55335-12-10	2426-55335-12-11	2426-55335-12-12
Sponsor Designation -	A-642	DOWEX 21K	PA 308	CR-11
Comments -				
Date Collected -				
Determinations in mg/L unless noted				
Total Dissolved Solids (@180 °C)	2,100	2,200	2,200	2,500
Chloride	1,100	1,100	950	98
Sulfate (as SO4)	<10	<10	<10	390

Notes:
[16] -- ADDITIONAL VALUE

By: Eyda Hergenreder

Eyda Hergenreder
Metals Laboratory Supervisor

By: Susan J. Barker

Susan J. Barker
Inorganic Chemistry Supervisor

EH/SJB/rt

QC INFORMATION

For Selenium

Duplicate (%RPD)

	#1 (T)	#2 (D)	#12 (D)
ICP	8	0	8
HGA	0	0	1

Spike

The spiking concentration was 0.050 mg/L. The samples were post digested spiked after dilution for furnace analysis. The spiking concentration was too low for ICP analysis.

	#1 (T)	#2 (D)	#12 (D)
HGA	94%	80%	90%

Reagent Blank

ICP	<0.05 mg/L
HGA	<0.005 mg/L

Laboratory Control Sample

ICP	97%	(TV = 1.0 mg/L)
HGA	99%	(TV = 0.080 mg/L)

Re: 2426-55335-12

Case Narrative

The values for selenium on the ICP are as follows:

ALR Sample Number	Sample Result mg/L
2426-55335-1	0.67
-2	0.70
-3	0.35
-4	0.34
-5	0.34
-6	0.34
-7	0.12
-8	<0.05
-9	<0.05
-10	<0.05
-11	<0.05
-12	0.31

The cation/anion balances were acceptable. The TDS balances were high. The samples were not reanalyzed for TDS due to limited sample amount.

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COMPLETED REPORT

ANALYSIS REPORT

DATE: 08/15/94 PAGE 1

J.C. LAUL
EG&G ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
P O BOX 464 BLDG 080
GOLDEN, CO 80402-0464

Lab Job Number: 2426-55646-4
Date Samples Received: 07/26/94
Customer PO Number: ASC233268JO3

These samples to be disposed of 30 days after the date of this report.

ALR Designation -	2426-55646-4-1	2426-55646-4-2	2426-55646-4-3	2426-55646-4-4
Sponsor Designation -	A-400	A-642	DOWEX 21K	PA308
Date Collected -	07/14/94	07/14/94	07/14/94	07/14/94
Determinations in mg/L unless noted				
Silver - total	<0.005	<0.005	<0.005	<0.005
Aluminum - total	<0.1	<0.1	<0.1	<0.1
Barium - total	<0.05	<0.05	<0.05	<0.05
Beryllium - total	<0.005	<0.005	<0.005	<0.005
Calcium - total	130	130	130	130
Cadmium - total	<0.005	<0.005	<0.005	<0.005
Cobalt - total	<0.005	<0.005	<0.005	<0.005
Chromium - total	<0.005	<0.005	<0.005	<0.005
Copper - total	<0.005	<0.005	<0.005	<0.005
Iron - total	<0.01	<0.01	<0.01	<0.01
Potassium - total	10	10	10	10
Lithium - total	0.39	0.39	0.39	0.38
Magnesium - total	56	58	58	57
Manganese - total	<0.005	<0.005	<0.005	<0.005
Molybdenum - total	<0.01	<0.01	<0.01	<0.01
Sodium - total	360	370	360	360
Nickel - total	<0.02	<0.02	<0.02	<0.02
Antimony - total	<0.05	<0.05	<0.05	<0.05
Selenium - total	0.29	0.26	0.26	0.27
Thallium - total	<0.1	<0.1	0.2	<0.1
Vanadium - total	<0.005	<0.005	<0.005	<0.005
Zinc - total	<0.005	<0.005	<0.005	0.077
Alkalinity, Total (as $CaCO_3$ to pH 4.5)	110	110	110	110
pH (pH Units)	7.4	7.9	7.8	8.0
Arsenic - total	<0.005	<0.005	<0.005	<0.005

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ANALYSIS REPORT

DATE: 08/15/94 PAGE 2
Lab Job Number 2426-55646-4

These samples to be disposed of 30 days after the date of this report.

ALR Designation -	2426-55646-4-1	2426-55646-4-2	2426-55646-4-3	2426-55646-4-4
Sponsor Designation -	A-400	A-642	DOWEX 21K	PA308
Date Collected -	07/14/94	07/14/94	07/14/94	07/14/94
Determinations in mg/L unless noted				
Mercury - total	<0.0001	<0.0001	<0.0001	<0.0001
Lead - total	<0.005	<0.005	<0.005	<0.005
Selenium - total	0.21	0.23	0.21	0.22
Nitrate (as N)	200	240	220	220
Total Dissolved Solids (@180 °C)	2,500	2,400	2,400	2,400
Chloride	260	240	260	230
Sulfate (as SO4)	310	330	310	320

TDS vs. ION BALANCE UNACCEPTABLE - UNABLE TO REANALYZE DUE TO LIMITED SAMPLE.

By: Susan J. Barker
Susan J. Barker
Inorganic Chemistry Supervisor

By: Evda Hergenreder
Eyda Hergenreder
Metals Laboratory Supervisor

SJB/EH/rt

Re: 2426-55646-4

Case Narrative

Selenium was analyzed by both ICP and Graphite Furnace.

QA results are as follows:

Reagent Blank

ICP	<0.05 mg/L
HGA	<0.005 mg/L

LCS

ICP	(TV = 1.0)	87%
HGA	(TV = 0.080)	99%

Spike Blank

ICP	(TV = 1.0)	99%
HGA	(TV = 0.050)	82%

Duplicate

ICP	0.29 and 0.29	0% RPD
HGA	0.21 and 0.22	5% RPD

Spike

ICP:	1.0 mg/L	HGA - 0.05 mg/L
#1	90%	88%
#2	96%	86%
#3	93%	86%
#4	78%	88%

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ANALYSIS REPORT

DATE: 08/25/94 PAGE 1

J.C. LAUL
EG&G ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
P O BOX 464 BLDG 080
GOLDEN, CO 80402-0464

Lab Job Number: 2426-55646-4
Date Samples Received: 07/26/94
Customer PO Number: ASC233268JO3

These samples to be disposed of 30 days after the date of this report.

ALR Designation -	2426-55646-4-1	2426-55646-4-2	2426-55646-4-3	2426-55646-4-4
Sponsor Designation -	A-400	A-642	DOWEX 21K	PA308
Comments -				
Date Collected -	07/14/94	07/14/94	07/14/94	07/14/94
Determinations in mg/L unless noted				
Alkalinity, Total (as $CaCO_3$ to pH 4.5)	110	110	110	110
Carbonate (as CO_3)	<5 [16]	<5 [16]	<5 [16]	<5 [16]
Bicarbonate (as HCO_3)	130 [16]	130 [16]	130 [16]	130 [16]
pH				
(pH Units)	7.4	7.9	7.8	8.0

Notes:
[16] -- ADDITIONAL VALUE

By: Susan J. Barker
Susan J. Barker
Inorganic Chemistry Supervisor

SJB/dh dh

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Appendix B

Acronym List

Am	Americium
ARAR	Applicable or Relevant and Appropriate Requirements
Be	Beryllium
Ca	Calcium
cc	cubic centimeters
CDPHE	Colorado Department of Public Health and Environment
COC	Contaminants of Concern
Cr	Chromium
DOE	Department of Energy
EPA	Environmental Protection Agency
ERPD	Environmental Restoration Program Division
Fe	Iron
FS	Feasibility Study
ft	feet
GFAA	Graphite Furnace Atomic Adsorption
HCI	Hydrochloric Acid
Hg	Mercury
K	Potassium
Kacl	Weathered Claystone
Kass	Unweathered Sandstone
mg/L	Milligrams per Liter
µg/g	Micrograms per Gram
µg/L	Micrograms per Liter
Mg	Magnesium
ml/min	Milliliters per Minute
µm	Microns or Micrometers

Mn	Manganese
Na	Sodium
NaOH	Sodium Hydroxide
ng/mL	Nanograms per Milliliter
Pb	Lead
pCi/L	Picocuries per Liter
pH	Hydrogen ion concentration
ppb	part per billion
Pu	Plutonium
QA/QC	Quality Assurance/Quality Control
RF	Retention Factor
RFEDS	Rocky Flats Environmental Database System
RFETS	Rocky Flats Environmental Technology Site
RFFO	Rocky Flats Field Office
Se	Selenium
SEP	Solar Evaporation Pond
STSP	Sitewide Treatability Studies Program
TDS	Total Dissolved Solid
TSS	Total Suspended Solid
TSWP	Treatability Study Work Plan
U	Uranium

66